NO. SU1
MARCH 1956

JOURNAL of the

Surveying and Mapping Division

PROCEEDINGS OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS

VOLUME 82

THIS JOURNAL

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JOURNAL

SURVEYING AND MAPPING DIVISION

Proceedings of the American Society of Civil Engineers

SURVEYING AND MAPPING DIVISION, COMMITTEE ON PUBLICATIONS
Lansing G. Simmons, Chairman.

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JOURNAL

SURVEYING AND MAPPING DIVISION

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PROFESSIONAL ASPECTS OF SURVEYING AND MAPPING

REPORT OF THE TASK COMMITTEE ON THE STATUS OF SURVEYING AND MAPPING

(Proc. Paper 921)

FOREWORD

The following report is being submitted to the Executive Committee of the Surveying and Mapping Division for their consideration and action. Largely self-explanatory, it deals with the status of persons engaged in surveying and mapping work in both governmental and private capacity, and covers an increasingly broad field of endeavor that has traditionally been intimately associated with civil engineering.

Throughout the report it is to be noted that photogrammetry, a relatively new tool, is not regarded as a major branch or category of surveying and mapping but is rather an important, extensive, and invaluable technique that is used in many branches of the work. The listing of "Aerial Survey Services" as a special category does not intend that all or even the most important uses of photogrammetry are therein included. Attention is called by footnotes to other major employment of this technique in almost all the other categories. Similarly, electronic measuring techniques, despite their newness are given their proper place in whatever category they serve.

The Task Committee believes this treatment of photogrammetry to be the logical basis for any proper future legislation. To single out this technique for special treatment as a branch of surveying, rather than as a tool is likely to result in less than wholesome and just registration laws.

Among all who are concerned with surveying and mapping there is a desire to retain its professional stature. To insist, however, that every operation no matter how slight is professional is to be unrealistic. An attempt is made on the basis of study of tradition and of present practice to differentiate between the skilled technician's work and work that must be considered beyond his scope and hence professional in nature.

Note: Discussion open until August 1, 1956. Paper 921 is part of the copyrighted Journal of the Surveying and Mapping Division of the American Society of Civil Engineers, Vol. 82, No. SU 1, March, 1956.

It is to be noted that the present report does not as yet represent the position of the A.S.C.E. or of the Surveying and Mapping Division.

The Surveying and Mapping Division of the Society was requested by the Board of Direction in October 1953 to study the activities of its membership and to classify the varied operations of surveying and mapping into professional, sub-professional, and non-professional. After considerable deliberation, the Executive Committee of the Division in October 1954 appointed the present Task Committee to work on this problem, as also to investigate the correlative question, whether all the professional activities in surveying and mapping should be recognized as civil engineering, or as a field of science apart from civil engineering.

It is the scope of the present report merely to achieve a distinction between the professional level and the technician level of activity in surveying and mapping, with a brief note regarding pre-professional work. Further study, it is recognized, will be needed to delineate adequately the activities which properly constitute engineering.

Attention is focussed in this report on the job positions and activities of the two classes of personnel—the professional practitioner and the skilled technician—as these occur in each of the six categories of surveying and mapping. It is necessary therefore at the outset to establish basic definitions for the terms: professional, pre-professional, and technician.

In defining "professional" the Engineers Council for Professional Development lists the following as attributes of a profession:

1) It must satisfy an indispensible and beneficial social need;
2) Its work must require the exercise of discretion and judgment and not be subject to standardization;
3) It is a type of activity conducted on a high intellectual plane;
    a) Its knowledge and skills are not common possessions of the general public; they are the results of tested research and experience and are acquired through special discipline of education and practice;
    b) Engineering requires a body of distinctive knowledge (science) and art (skill);
4) It must have group consciousness for the promotion of technical knowledge and professional ideals and for rendering social services;
5) It should have legal status and must require well-formulated standards of admission.

The E.C.P.D. further says of professional practitioners:

1) They must have a service motive, sharing their advances in knowledge, guarding their professional integrity and ideals, and tendering gratuitous public service in addition to that engaged by clients;

2) They must recognize their obligations to society and to other practitioners by living up to established and accepted codes of conduct;
3) They must assume relations of confidence and accept individual responsibility;
4) They should be members of professional groups and they should carry their part of the responsibility of advancing professional knowledge, ideals, and practice.[1]

As additional interpretation of this definition of the profession, Mr. Lloyd E. Blauch, Specialist in Higher Education, U.S. Office of Education, has enumerated eleven characteristics of a profession:

1) Performance on the intellectual rather than on the instrument level;
2) A distinctly practical object, not merely academic or theoretic;
3) A specialized intellectual technique acquired through prolonged training;
4) The use of independent judgment and the assumption of large personal responsibility;
5) A field of service that encompasses research and creative activity;
6) A body of specialized literature;
7) Capable, above average, well educated personnel;
8) Schools on the college and university level;
9) Social cohesiveness and organization of those engaged in the calling;
10) Some type of social regulation;
11) A considerable amount of liberal or general education.[2]

It is appropriate to cite also the definition of the term "professional employe" as given in the language of the Taft-Hartley Act of 1947:

The term "professional employe" means:

a) Any employe engaged in work
   i) Predominantly intellectual and varied in character as opposed to routine mental, manual, mechanical, or physical work;
   ii) Involving the consistent exercise of discretion and judgment in its performance;
   iii) Of such a character that the output produced or the result accomplished cannot be standardized in relation to a given period of time;
   iv) Requiring knowledge of an advanced type in field of science or learning customarily acquired by prolonged course of specialized intellectual instruction and study in an institution of higher

1. E.C.P.D. Thirteenth Annual Report, 1945, p. 29.
2. American Journal of Pharmaceutical Education, 1948, p. 243.

learning or a hospital, as distinguished from an apprenticeship or from training in the performance of routine mental, manual, or physical processes;

or;

b) Any employe who
   i) Has completed the courses of specialized intellectual instruction and study described in clause (iv) of paragraph (a) and
   ii) Is performing related work under the supervision of a professional person to qualify himself to become a professional employe as defined in paragraph (a).

As a final basis for definition, the pamphlet "The Engineering Technician" published by the Technical Institute Division of the American Society for Engineering Education is cited. The publication outlines the functions of the three men on the "engineering team": the engineer, the engineering technician, and the skilled craftsman:

The place of the Engineer --

A professional engineer's work is mostly mental in character. He studies and reasons and visualizes how bits of knowledge can be put to practical use. The vast majority of engineers do not need manual dexterity with tools. Among the activities they engage in are the design of tools, structures, mechanisms, curcuits or processes; the layout of industrial processes; research and development; controlling the quality of manufactured products through testing and inspecting; and planning systems for the distribution of power and for electronic communications.

The Place of the Engineering Technician --

An engineering technician engages in work that requires some of the knowledge and skills of both the professional engineer and the skilled craftsman. He is required to know basic theories and to apply them in helping to solve the complex problems of modern industry. In this way the engineering technician carries out vitally important assignments and takes his place on the engineering team.

The engineering technician usually specializes in one aspect of engineering. He might, for example, work as a draftsman, a detail designer, a cost estimator, a production supervisor, a research assistant, a quality-control supervisor, a time-study man, an expediter, a technical salesman, or a production planner.

The Place of the Skilled Craftsman --

The work of the engineer and the technician would be meaningless without the contribution of the skilled craftsman who carries out the

engineering ideas. A toolmaker, for example, fabricates a jig or die from a design conceived by the engineer and detailed by the technician. The electrician, pipefitter, welder, machinist, chemical operator, and surveyor's rodman likewise use their skills to carry out the work of the engineering team.[3]

In the outline that follows, there is a distinction made between the professional and the technician. The proper determination of the dividing line rests on the understanding and application of the definitions of professional and technician work as set down in the beginning of this report. An exhaustive listing is not attempted for these positions, nor is there given any but the highest grades of technician or pre-professional activity.

The tenets used for the differentiation throughout the study are as follows:

PROFESSIONAL LEVEL -- Work performed by such a person involves the exercise of professional judgment, frequently based on knowledge acquired through higher learning, generally non-routine in character. The term implies one who can plan, perform, and/or direct all such operations in the category; this person is responsible for work performed by those under him.

TECHNICIAN LEVEL -- Work performed by such a person is primarily routine, of a technical nature, often demanding a higher degree of skill, done under the direction of a professional person who is responsible for its outcome.

PRE-PROFESSIONAL LEVEL -- Work at the technician level performed by a professional trainee who, having completed courses of specialized intellectual instruction and study, is seeking to attain professional status.

DEFINITIONS OF PROFESSIONAL POSITIONS

As a guide to the terms used for designating the several professional positions in the preceding outline, it is though advisable here to include certain definitions. These follow generally the accepted definitions as given in A.S.C.E. Manual No. 34, "Definitions of Surveying, Mapping, and Related Terms" 1954, but are altered somewhat to more clearly describe the particular job function envisioned in this outline.

LAND SURVEYOR -- determines location of land boundaries; prepares map showing shapes and areas of land; divides land into smaller tracts, including layout of roads and streets and rights-of-way to same to give access to smaller tracts; prepares official plats or maps of such land subdivisions; prepares and interprets land descriptions for incorporation in deeds, leases, etc.

3. "The Engineering Technician", Technical Institute Division of the American Society for Engineering Education, pgs. 2 and 3.

CLASSIFICATION OF POSITIONS

	PROFESSIONAL LEVEL***	TECHNICIAN OR PRE-PROFESSIONAL LEVEL****
I. LAND SURVEYING (Cadastral)		
A. Property and Boundary Surveys*	Land Surveyor	Instrumentman
B. Subdivision Surveys and Plats*		Computer
C. Public Lands Surveys*		Draftsman
D. Surveys for Plans and Plats*		Tapeman
1. Architectural (Building-Site) Surveys		Rodman
2. Tax Maps		
II. ENGINEERING SURVEYS FOR DESIGN AND CONSTRUCTION		
A. Design Data Surveys (including Route Surveys)*	Survey Engineer	Instrumentman
1. Control, horizontal and Vertical		Computer
2. Culture and Topography		Draftsman
3. Profiles and Cross-Sections		Tapeman
B. Construction Surveys*		Rodman
1. Lay-out Surveys		
2. Quantity and Measurement Surveys		
3. 'As-Built' Surveys		
a. Utility Surveys		
C. Mine Surveys		
III. GEODETIC SURVEYING, GEODETIC ENGINEERING, or GEODESY (not to be confused with precise land surveying)		
A. Control Surveys, first- and second-order accuracy**	Geodetic Surveyor or Geodetic Engineer	Instrumentman
1. Horizontal: triangulation, traverse, and electronic trilateration		Observer
		Computer
	Mathematician	Gravimetric Operator
2. Vertical: spirit and trigonometric leveling		Recorder
B. Geodetic Astronomy		Signalman
C. Gravity Surveys, Magnetic Declination Surveys, Figure-of-the-earth studies		Tapeman
		Rodman

* Photogrammetric procedures used when applicable on these and other activities.
** Electronic measuring procedures used when applicable on these and other activities.
*** See definitions following this outline.
**** Including some which are normally skilled craftsmen but which sometimes, by reason of special training, are properly considered technicians, e.g., rodman, tapeman, leadsman, signalman, etc.

SURVEY ENGINEER -- obtains information for planning or developing an engineering project and estimating its cost, often recording such information in form of an engineering map or plat.

GEODETIC SURVEYOR (OR ENGINEER) -- plans, performs, or supervises high-accuracy surveys as well as the computations and adjustments thereof, including such as triangulation, traverse, precise leveling, and astronomic observations, such surveys being of a magnitude that the required accuracy and precision can be obtained only through processes that involve figure and size of the earth.

IN SURVEYING AND MAPPING

	PROFESSIONAL LEVEL***	TECHNICIAN OR PRE-PROFESSIONAL LEVEL****
IV. CARTOGRAPHIC SURVEYING, CARTOGRAPHIC ENGINEERING, or MAP AND CHART SURVEYING (Surveys for constructing original maps and similar products)		
A. Control Surveys, third- and fourth-order accuracy**	Control Surveyor	Plane-table Operator
1. Horizontal		Instrumentman
2. Vertical		Observer
B. Topographic-Planimetric Surveys and Maps*	Topographer	Computer
		Recorder
1. Photogrammetric Aero-triangulation	Photogrammetrist	Draftsman
2. Mapping Surveys		Tapeman
		Rodman
a. Ground-survey methods		
b. Photogrammetric methods		
3. Field-edit surveys of photogrammetric compilations		Stereo-plotter Operator
C. Hydrographic Surveys**	Hydrographer	Observer
1. Soundings: fathometer, hand-lead, sounding pole		Recorder
		Computer
2. Sounding fixes: three-point, electronic		Draftsman
		Leadsman
3. Wire-drag surveys		
4. Tidal and current surveys		
V. AERIAL SURVEY SERVICES		
A. Aerial Photography	Photogrammetrist	Photographer
1. Photo-interpretation	Electronic Engineer	Photo-lab Technician
B. Electrical Measurements for distances and position fixes (Shoran, etc.)	Mathematician	Photo-interpreter
	Geophysicist	Computer
C. Airborne Magnetometer Surveys		Electronic Technician
D. Radar-altimeter Profiles and Elevations		Magnetometer Operator
		Radar-altimeter Operator
VI. CARTOGRAPHY (not requiring original surveys)		
A. Map Design	Cartographer	Map Compiler
B. Compilations derived from existing source data	Geographer	
1. Evaluation of maps and other source data		
2. Nautical and aeronautical charts, topographic and planimetric maps, special-purpose maps, etc.		
3. Photomaps and Mosaics		Mosaicker
4. Relief Maps and Models		Modeler
5. Radar-Prediction Charts		
C. Map Editing	Map Editor	
D. Map Reproduction		Engraver
1. Engraving or equivalent		Lithographer
2. Lithography		

CONTROL SURVEYOR -- plans, performs, or supervises surveys and computations of horizontal and vertical measurements involving complex network adjustments, etc.

TOPOGRAPHER -- plans, performs, or supervises the construction of topographic maps of any scale, contour interval, or accuracy specification, including all surveying procedures and calculations required for such map construction; determines when and whether ground or photogrammetric surveys, or various combinations thereof, shall be used.

PHOTOGRAMMETRIST -- plans, performs, or supervises use of photogrammetric instruments and techniques in conjunction with various aspects of surveying, mapping, resource surveys, and the design of photo-interpretation systems.

CARTOGRAPHER -- plans construction and compilation of charts and maps of small scale; assembles, evaluates, selects, and directs plotting of data therefor.

MAP EDITOR -- performs many functions of the cartographer; especially designs form and content of maps; determines criteria for symbolization and nomenclature; reviews manuscript maps as to accuracy, completeness, correctness, and conformity with established standards.

The titles mathematician, electronic engineer, geographer, geophysicist, etc., are not defined herein specifically, since these are primarily persons in allied professions whose work only incidentally is in the field of surveying and mapping.

CONCLUSION:

The foregoing classification of positions should serve as a fundamental basis for any future study in the field of surveying and mapping. It would necessarily precede any attempt to determine the engineering or non-engineering status of surveying and mapping activities.

Respectfully submitted,

Brother B. Austin Barry
Chairman

George D. Whitmore
Alfred O. Quinn

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PROGRESS IN TOPOGRAPHIC MAPPING[1] FROM 1946 TO 1955

Gerald FitzGerald[2]
(Proc. Paper 922)

History of Topographic Mapping

In order to evaluate the accomplishments in the production of topographic maps of the United States and to give them a proper perspective it seems appropriate to review briefly changes which have occurred in the mapping art since the establishment of the Geological Survey in 1879.

Topographic mapping has always been a major activity of the Geological Survey. The Hayden, Wheeler, Powell, and King surveys, which were in effect consolidated to form the new Survey under the Department of the Interior, were equipped and trained to conduct geographic exploration and to do topographic mapping. Clarence King, the first director, after discussing functions of the new organization with members of Congress concluded in part "that the intention of Congress was to begin a rigid scientific classification of the lands of the national domain for the general information of the people of the country and to produce a series of land maps which would show all those features upon which the intelligent agriculturists, mining engineers, and timbermen might hereafter base their operations and which obviously would be of the highest value to all students of the political economy and resources of the United States." Topographic mapping therefore was made a part of the work of the Survey and funds were allotted each year from 1879 to 1888 for mapping surveys. Thereafter, up to and including the present year Congress has made annual appropriations to the Geological Survey specifically for topographic surveys.

Early mapping scales and methods were geared to produce reconnaissance quadrangle maps as rapidly as possible, particularly of vast areas in western United States. As scales increased and accuracy became a bit more important, time and compass traverse and the aneroid barometer were replaced by the planetable and the telescopic alidade with its vertical angle arc. In 1896 Congress authorized the Geological Survey to execute spirit leveling and to

Note: Discussion open until August 1, 1956. Paper 922 is part of the copyrighted Journal of the Surveying and Mapping Division of the American Society of Civil Engineers, Vol. 82, SU 1, March, 1956.

1. Publication authorized by the Director, U. S. Geological Survey.
2. Chf. Topographic Engr., Geological Survey, U. S. Dept. of The Interior, Washington, D. C.

set permanent bench marks for the control of mapping. The use of aerial photography and photogrammetry began to play an important part in mapping operations in the period between World War I and World War II. In spite of this new development however the country's mapping program lagged so badly between the two World Wars that only 20 percent of the United States was covered by maps that were needed for national defense when Pearl Harbor was attacked. Mapping in the United States and in fact throughout the world received its greatest impetus during the last War. The imperative demands for maps on which to plan defensive or offensive military action required greatly increased activity on the part of public and private organizations.

Scientific and engineering research, applied to the development of precision mass production methods, effectively supplied equipment and materials to our armies during World War II. In a like manner, scientific and engineering research was concentrated upon the mapping problem and towards the development of precision mass production methods and techniques, involving in many cases designing new instruments and new photogrammetric equipment. A resume of the accomplishments of this program during the past ten years is the substance of this paper.

While many techniques for the use of photogrammetry in topographic mapping had been developed before and during World War II, the development of efficient mass production methods was left for the postwar era. In some respects this change was revolutionary. It has meant a radical departure from the methods of the past to a new and modern concept comparable to that which has occurred in many other fields.

The ten years since the cessation of hostilities at the end of World War II have brought changes into the lives of all of us that have raised the standard of living of our people to the highest ever achieved in history. These changes, which also have made us more map conscious, have largely been the result of the application of scientific and engineering research in every line of endeavor from management to manufacturing and distribution. The impact of these changes is brought into sharp focus when we realize that practically no one had a television set ten years ago and that travel by plane was rather an expensive luxury.

To keep pace with this expanding economy and our growing population there has been an increasing demand for new industrial plants and power facilities, millions of homes with their attendant shopping centers, schools, churches, and recreational areas, and improved highways and transportation routes. These extensive demands for new developments of all kinds have created a corresponding requirement for more and better maps for use in investigation and planning suitable sites for these installations. This large civilian demand was added to the already extensive high priority map requirements of the Department of Defense.

Another factor which compounded the problem of supplying the required maps was the increasing demand for larger scales. Whereas the 15-minute map at 1:62,500 scale was generally adequate prior to Pearl Harbor, needs developed for the 7 1/2-minute map at 1:24,000 scale for many areas in the postwar period. The increased cost of the larger scale maps affects the coverage possible with available funds.

The Last Ten Years, 1946-1955

The Topographic Division is one of the four technical divisions of the Geological Survey. Since 1946 its principal components have been a Washington staff headquarters office; four region operations offices (located at Arlington, Va., Rolla, Mo., Denver, Colo., and Sacramento, Calif.) and a Special Maps Branch in Washington. The Washington staff handles short- and long-range planning, program coordination and control, research in equipment and techniques, map specifications, and the development of mapping procedures. The four region offices carry out detailed planning of the actual mapping operations, the field surveys, the laboratory operations such as stereophotogrammetric map plotting, the smooth-line drafting or scribing, and the map editing. The Special Maps Branch devotes its particular talents to the preparation of small-scale maps and charts, including at the present time maps of the Antarctic in connection with the International Geophysical Year and the operations of Task Force 43. Map materials prepared in the region operations offices and the Special Maps Branch are printed in Washington.

The general plan of 10 years ago for greatly expediting the completion of the topographic mapping of the country included increased emphasis on the use of the most modern techniques in the preparation of maps; the adoption of engineering standards of accuracy for all surveys and maps; a greatly expanded research and development activity in search of instruments and techniques that would result in higher accuracy or lower costs; and a program planning and program control activity that would make it possible to use the field and office forces effectively and economically, reducing to a minimum the peaks and valleys in the annual production schedules. This activity, it can be seen, is a formidable undertaking in view of the necessity of keeping an operational plan current for a 4- to 6-year period for all of the production phases of the nearly 10,000 quadrangles that have been authorized for mapping.

The production procedures were planned to make maximum use of photogrammetry, which in turn would be based on and supplemented by conventional field surveys to the extent necessary to maintain the specified accuracy and completeness of content. The major phases of the production cycle are aerial photography, control surveys, preparation of photogrammetrically compiled original map drawings, and field completion surveys as necessary to check the map and make it complete. These are followed by the map-finishing operations, which include color separation by smooth drafting or scribing, map editing, and reproduction by photolithography.

Although the general procedures in use today are not basically very different from those adopted ten years ago, they have been modified considerably as a result of our research and development activities. For example, the staff photogrammetry section, set up immediately after World War II, has as one of its prime objectives the exploitation of photogrammetry to its fullest through the medium of research. The attack on the problem was made simultaneously on three interrelated major fronts—aerial photography, photogrammetric instruments, and techniques and standards. Thus the concept of a "system" was evolved whereby all of the elements required to accomplish the goal of photogrammetrically compiled topographic maps more efficiently were considered as a unit, and the development work on any one element did not proceed until its effect on the system as a whole was determined.

Successful photogrammetry-for-mapping starts with intelligent planning of photographic coverage to facilitate ground-control and photogrammetric

operations. Much original work has been done in this field by the Survey, including adoption of base- and width-height ratio instead of percentage forward or side overlap for defining coverage of aerial photography. Precision mapping cameras, camera-calibration techniques and twin-camera mounts have been the subject of intensive research and development which has paid large dividends in the form of better mapping photography.

Stereoscopic plotting equipment has received the lion's share of attention during the past ten years. The multiplex and its accessories, the diapositive printer and the tracing table, have all been greatly improved and perfected through research. The Kelsh plotter developed by H. T. Kelsh and other members of the Geological Survey during the past ten years has made an important contribution to stereomapping and is widely used by government agencies and private industry.

Perhaps the most important development in mapping photogrammetry in recent years has been the development of a system for the effective use of twin low-oblique photography. The Twinplex plotter when equipped with ER-55 projectors, both of which were developed by Russell Bean and his associates in the Geological Survey, provides one of the most efficient and modern means known for compiling medium- and small-scale topographic maps when used with twin photography. Other developments perfected and adopted by the Survey to increase map accuracy and decrease costs are the variable-ratio pantograph for use on photogrammetric plotting equipment, and stereotemplets, a new and highly effective tool for the extension of horizontal ground control. A recent development is the orthophotoscope, an instrument which has been engineered and designed to convert conventional perspective photographs to the equivalent of orthographic photographs for use in mapping, engineering, geology, forestry, and other scientific fields.

Photogrammetric research carried on by the Topographic Division during the past ten years has paid off in better maps and lower costs. It is one of the major reasons why during fiscal year 1955, despite manpower reduction of approximately 5 percent, the output of the Division measured in square miles of mapping was increased by 25 percent compared to production in the previous year. Costwise this research represents less than one percent of our total budget. We are confident that continued investigations into better photogrammetric methods will reduce our overall mapping costs.

The basic procedures for control surveys for topographic mapping, a relatively costly operation, have not changed materially in the past ten years, although numerous experiments have been conducted with new instruments and techniques, including various applications of electronics for measuring distances and heights. It happens that most of the newer techniques are not yet economical for topographic mapping control work. However, the use of helicopters for the transportation of control-survey personnel, particularly in western United States and Alaska, has greatly expedited the field work of control surveys. The Geological Survey pioneered that method of transportation in 1948 and has used it successfully since that time.

An important development during recent years is a technique known as scribing, a method of engraving map details through a semi-opaque coat of paint applied to a clear plastic sheet, a method that is similar to the negative-engraving technique used in photolithographic reproduction processes. Scribing has already been fully adopted in the color-separation phase of the map-finishing operation, resulting in an improved appearance at a greatly stepped up rate of production. Of even greater significance, perhaps, are the current

experiments in the use of scribing instead of pencilling or inking on the original photogrammetrically prepared map drawings, and on the planetable sheets in the field. One experiment now under way is intended to determine the feasibility of separating the colors of the map at the time of photogrammetric compilation, which, if successful, would further expedite the production cycle and reduce costs.

A Decade of Progress

Topographic mapping by the Geological Survey has increased tremendously during the past ten years. The average output before World War II was 100 or less maps a year. During fiscal year 1946, the beginning of our ten-year period, 227 topographic quadrangle maps of the country as a whole were published. This annual production has increased steadily so that we can report a total of 1,547 for fiscal year 1955, the last year in the decade we are here considering.

The increase in production over what was realized during the prewar years is, of course, closely related to increases in the funds made available for topographic mapping. The amount for this activity for fiscal year 1946 was about $5,000,000. This amount increased to a high of about $17,200,000 in 1952, due in part to the transfer of about $4,700,000 from the military for urgently needed mapping, then leveled off at about $14,700,000 through 1955. Although production is directly related to available funds, a unique relationship has occurred during the closing years of the period under discussion. Available funds are less but production has continued to increase. This relationship is mainly the result of two important influences that combine to increase production. One is a more stable and better trained operating force, the other is applied research, the continual effort devoted to the improvement of instruments and techniques.

The funds made available for topographic mapping include offerings from the States and other municipalities under the terms of cooperative agreements. Such cooperation is on a 50-50 basis, and has increased from about $468,000 in 1946 to $1,233,000 in 1955, at which time 33 States and Puerto Rico were cooperating.

A new cooperative program was started in Kentucky in 1949 to map the entire State at a scale of 1:24,000 in a period of five years. This program has been completed and a continuous cooperative revision project is under way. California has a large annual program, and since 1947, 63,000 square miles of new mapping and 21,000 square miles of revision have been completed in the State. Cooperative mapping in any State in any amount is a valuable and significant contribution to the completion of the mapping of the country.

Mapping requested by the Department of Defense has occupied nearly half of the Survey capacity during the past ten years and planned mapping for immediately foreseen military purposes will not be completed until 1965. This program involves mapping in 48 States, Alaska, and the Hawaiian Islands, and totals nearly a million square miles.

In 1946 mapping was started as part of the Missouri River Basin Development Plan and is still under way. About 80,000 square miles have been mapped under this program.

In addition to the preparation and publication of more than 10,000 new quadrangles of the 7 1/2- and 15-minute series during the past ten years, several other major projects have been undertaken. The first uniform series of topographic maps of Alaska were compiled at high speed from existing

source materials and published at a scale of 1:250,000 for the entire 600,000 square miles of the Territory. The 157 maps comprising this series, although provisional in nature, represented a fitting culmination of the Survey's fifty years of mapping activity in the Territory. Also, more than 100,000 square miles of mile-to-the-inch mapping has been completed since 1948 in the more important parts of Alaska, and nearly 500 quadrangles have been published. As the Department of Defense has placed a high priority on Alaska mapping, the current program calls for about 400,000 additional square miles of mile-to-the-inch mapping by 1962, together with complete revision of the "quarter-million" scale provisional series.

Specifications and standards of the State base maps at a scale of 1:500,000 have been revamped, and many of the new maps have been published. Others are in preparation and will be completed as new source data become available.

A new technique for the relief shading of maps has been perfected in the Survey. This method has been used on the 1:250,000-scale maps of Alaska, on many of the 1:500,000-scale State base maps, and on dozens of individual 7 1/2- and 15-minute quadrangles portraying unusual physiographic features.

In response to a widespread demand, special-format maps of the more important cities of the country are being prepared and published at the 1:24,000 scale. These are especially adapted to the use of civil and military defense activities.

The Special Maps Branch has compiled maps of 7 1/2 million square miles of various parts of the world for the United States Air Force. It has also completed several special mapping projects for all divisions of the Survey, the Atomic Energy Commission, the Navy Hydrographic Office, the President's Water Policy Commission, Forest Service, Corps of Engineers, National Park Service, Bureau of Public Roads, Federal Power Commission, and other Federal agencies.

The increased production of topographic maps has focused attention on the matter of distributing them to the public. Distribution is accomplished through three principal outlets located in Washington, D. C., Denver, Colo., and Fairbanks, Alaska. In addition, the operation is assisted by 11 other Survey offices located in the West and by 425 commercial agents located throughout the United States and Alaska. During the 10-year period, the annual rate of distribution of maps rose from 1,000,000 copies in 1946 to 3,200,000 copies in 1955. It is expected that the number of maps distributed during fiscal year 1956 will reach 4,000,000 copies. The rapid rate of increase experienced over the past three or four years is a result of the expanded coverage provided by the increasing volume of new maps published together with a broadening knowledge of the availability of Geological Survey maps.

Under the expanding program of production and distribution, attention has also been paid to developing a better system of determining the map user's requirements. In conjunction with the Bureau of the Budget, the Geological Survey has developed a system whereby the principal Federal map-using agencies, about 20 in number, submit their map needs to the Survey annually. The procedure also provides for determining the needs of State agencies. In this regard, mapping advisory committees have been formed in 17 States. Several more are in process of being organized and it is hoped that eventually all the States and Territories will have representative committees to review the mapping situation, to recommend priorities, and to consult with the Survey on specifications.

The Future Program

In 1946, when a proposal was made to the Bureau of the Budget for completing the topographic mapping of the country, it was estimated that about 25 percent of the United States was adequately mapped, and that the cost to complete the job would be approximately $400,000,000.

Although the cost of all the elements that go into the making of a map, such as salaries, transportation, equipment, and supplies, have greatly increased, and the funds available for topographic mapping have been only about one-half the amount recommended in the 1946 proposal, much has been accomplished. In terms of percentage, during the last fiscal year (1955) new mapping was completed for about 4 percent of the country. At the present time, 37 percent of the country is adequately mapped according to our current appraisal of published quadrangle maps.

On the basis of our presently available funds, anticipated rate of accomplishment, and in accordance with our present concept of map scales and content, complete topographic quadrangle map coverage for the remainder of the United States could be accomplished in approximately 17 years at a cost of about $220,000,000.

This cost estimate for the job remaining, when added to the funds available during the past 10 years, indicates that the present estimated cost of doing the job that was proposed in 1946 is about $328,000,000. This new estimate, lower than the 1946 estimate by nearly 20 percent in spite of inflation, is principally a reflection of the more efficient procedures that have been brought through our research activities.

At this time it would not be possible to foresee, or feasible to provide, all the mapping that future generations may require. The need for more detailed surveys of limited areas will undoubtedly arise—usually in connection with specific engineering undertakings, as one of the details of project planning. Also, technological developments or the increased intensity of land use may at some future time require mapping far beyond that visualized in this program. The national mapping program of the Geological Survey, however, is in line with the requirements of the present and the foreseeable future. It is believed that this mapping program will meet those requirements.

JOURNAL

SURVEYING AND MAPPING DIVISION

Proceedings of the American Society of Civil Engineers

SURVEYING AND MAPPING FOR THE AIR FORCE ACADEMY[a]

Edward A. Merrill,* M. ASCE
(Proc. Paper 923)

SYNOPSIS

The problem of master planning and design of a major installation on a complicated site must be based on adequate knowledge of the topography. A description of the procedures utilized with illustrations showing the site, the characteristics of which influenced these procedures, and typical maps developed for use.

INTRODUCTION

This discussion of the surveys and maps for the Air Force Academy is presented from the viewpoint of the Architect-Engineer rather than the Aerial Surveyor, Photogrammetrist or Topographer. The Architect-Engineer requirements vary with the special conditions relating to the design problem, the construction program and the site itself, although there may be a general similarity between different projects from which inferences can be drawn with relation to future problems. Actually the Academy problem was not unusual, topographically, except perhaps in degree, due to the installation of a widely publicized permanent Federal project to be designed and constructed in its entirety from a paper program to a complete useable facility in a relatively short time and on a site representative of relatively virgin terrain. The analysis of the procedures, which are described, must always bear in mind the individual nature of this particular undertaking but it does not claim startling innovations nor attempt the establishment of standard procedures. As is the case with any interchange of experience by engineers, it is hoped that, it may be of value to those having similar problems.

Note: Discussion open until August 1, 1956. Paper 923 is part of the copyrighted Journal of the Surveying and Mapping Division of the American Society of Civil Engineers, Vol. 82, No. SU 1, March, 1956.

a. A paper prepared for presentation at the Annual Convention of the American Society of Civil Engineers, New York, N. Y. October 1955.

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Generally, an architect requires topographic information for three purposes; First: for the Master Planning of the entire installation; Second: for the detailed design of its elements and; Third: for the control of construction. In addition, the owner requires accurate maps as a part of his records, for the proper maintenance of his physical plant, and as an aid in planning future construction.

In order to evaluate the particular problem, it is necessary to understand the particular site. In this case, it consists of relatively undeveloped ranch land lying between the Rampart Range of the Rockies, and U. S. Highway 85-87, connecting Denver with Colorado Springs, which, at the Academy Site about ten miles north of Colorado Springs, is a strip approximately six miles wide. The final boundary enclosed land with a variation in elevation of nearly 2,000 feet—from 6,300 to 8,200 feet above sea level. Initial major construction will occupy areas as high as 7,600 feet. On the west are the still steeper slopes of the range and the Pike National Forest—an ideal protection against encroachment. The site is featured by alluvial fans cut by intermittent water courses forming alternate mesas and arroyos which lead eastward from the range toward the main drainage channel of Monument Creek flowing south, parallel with the highway and the two railroads which follow its valley. With the exception of a few motels along the highway, developments on the site are limited to ranch structures and scattered residences.

In the development of a Master Plan, the topography of the site is most important. There are many elements which must be resolved by the Master Plan—actually their resolution is the Master Plan. Since the grade and drainage characteristics of the land determine buildable areas, the Architect plotted on the maps and models the drainage lines and the land areas with slopes from 0 to 5 percent and from 5 to 10 percent—about the maximum grade capable of building development without major earth moving problems—to determine the actual extent and location of useable areas particularly in the more pleasant land toward the west. Access to existing transportation arteries, together with reasonable grade, determines the traffic circulation plan. Vegetation, particularly tree cover, influences siting of facilities since it is planned that the present magnificent scenic character of the site will be disturbed as little as possible. On many sites, existing structures available for use will influence planning, but, in this case, only a Country Club building, which will be the permanent NCO Club, and one or two industrial installations are available, although present ranch buildings and motels will be utilized during construction. In addition, in the case of the Academy, there are two special features related to the site which influence the Master Plan. One; the desire of siting the monumental structures most effectively from the standpoint of observation and approach from motor entrances on the highway; and, second, the location of an airfield with all the consideration which must be given to flight approach zones as well as to the actual construction of the aircraft utilization areas. This latter requirement, of course, involved consideration of the topography for miles beyond the site on all sides.

Finally, a special requirement of this project was the actual selection of the site boundaries. In the consideration of Colorado Springs for the Academy, the Air Force had been offered the general area which has been described. The Congressional Committee action which authorized the planning, had stipulated a maximum area of 15,000 acres. It was a part of the architects' job to recommend the actual boundaries for the Academy, considering not only the net ground area to be covered by buildings, pavements, parade grounds and

playing fields, but proper separation of elements and protection from possible undesirable marginal developments, particularly along the highway. These studies led to recommendations for an increase in area to 17,500 acres, which has been approved.

Before detailed design could start, the program for the Academy had first to be developed from the descriptive and statistical requirements established by the Air Force, to determine precisely what buildings, utilities and other facilities would be required for the mission. This paper is not concerned with the detail of this program, but greatly simplified, it involved so far as site planning was concerned, the proper location of seven principle areas; A Cadet Area for the housing, training and educational facilities for 2,600 Cadets; Housing for 400 families of faculty and service personnel plus BOQ's and barracks for the support troops; the Community Center with schools, churches and the shopping and recreational facilities for this small city; the Air Strip and supporting facilities; the Supply Area with warehouses, shops, and related facilities; the Athletic Fields for the cadet component; and a Maneuver Area. Each of these facilities had its own requirements not only determining size but influencing its position relative to the others. For all of this, expansion to support a 100 percent increase in the cadet component must be provided.

Obviously, this design job called for maps and, when the work started in August, 1954, the maps on which the initial design studies could be based, were limited to the published maps of the U. S. Geological Survey, and the Army Map Service. The largest scale available was 1/24 000 with a contour interval of 20 feet in the easterly quadrants and 40 feet in the rougher terrain toward the west. In addition, the two quadrants which cover the northerly half of the proposed area were then available only in uncorrected advance copies of unpublished U.S.G.S. sheets. While these maps were most helpful to the extent that preliminary design could not have started without them, they were, of course, entirely inadequate for detailed planning.

Recognizing this fact, as soon as the site was selected and prior to the selection of the Architect-Engineer, the Air Force had entered into a contract with Alster and Associates, of Washington, D.C. for photogrammetric mapping of the area. This contract called for maps at scale of 1" to 400' with 5' contour intervals over the general area to be followed by maps at the scale of 1" to 100' with 2' contour intervals over the final site. Specifications, as usual, required third order accuracy for control, maximum horizontal displacement of 0.025", and vertical accuracy equal to one-half the specified contour interval all for a minimum of 90 percent of the work. The map sheets were issued to the Architect-Engineer as they were completed, the 400' series first, in accordance with a priority schedule set up to fit the design program. The work was completed in May 1955 with delivery of the final sheets of the 100' series. They were, of course, absolutely indispensable. The design could not have approached the present stage without them, and it is unnecessary to discuss the increase of time and cost which would have been involved in obtaining the necessary topographical information by other means.

The sequence of map development is illustrated by the first figures. Figure 1 is a composite made from the four quadrants of the U.S.G.S. maps which were initially available. On this and on succeeding maps, there is drawn the final Academy boundary, established, of course, much later, to serve as a common reference. In order to develop the preliminary drawings at a uniform and more convenient scale, these maps were photographed up to 1" to 1,000' (1/12 000), which had been determined as the basic scale of the Master Plan

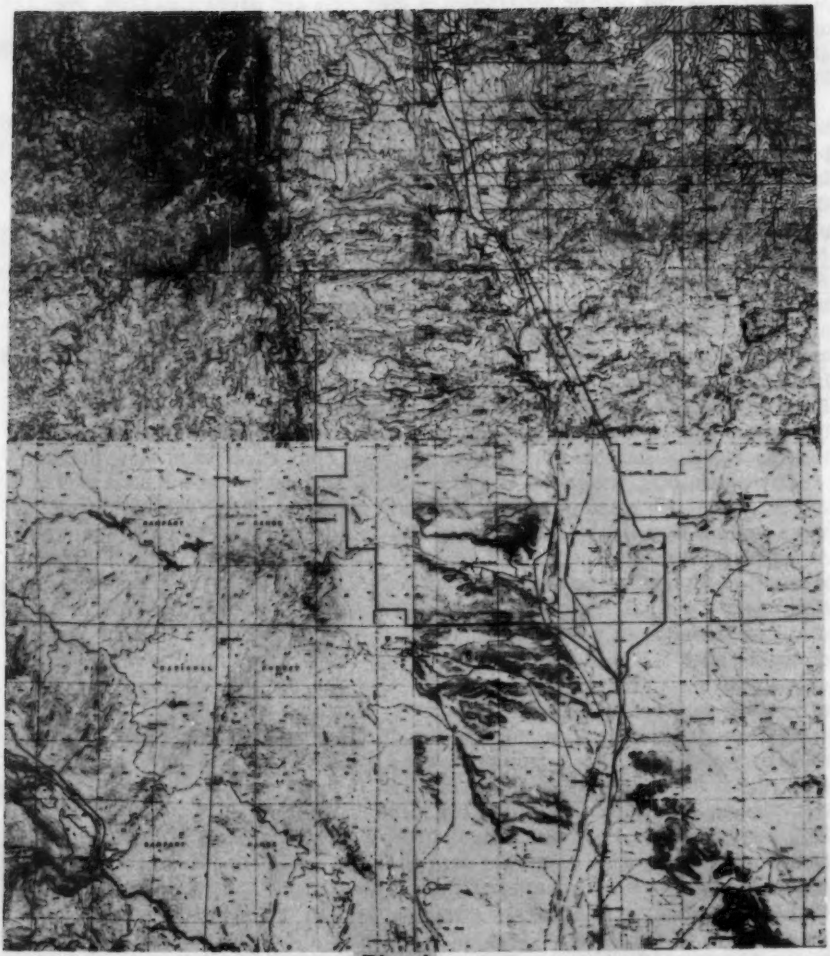

Fig. 1

Tabs. This map (Figure 2) is shown to compare the information available from it with that on the photogrammetric maps which follow. The final coverage of the photogrammetric maps is shown on the Alster map index on Figure 3. For purposes of detailed discussion of the later figures, the 1" to 400' sheet in which is located the Cadet area (Alster Map Sheet No. 6, Figure 4) is outlined and the 1" to 100' sheet (Alster Map Sheet No. 43, Figure 5) is blocked in.

As soon as the new maps were available, the U.S.G.S. sheets were discarded and, for the Master Plan studies, a mosaic of the 1" to 400' sheets assembled and photographed down to the required scale of 1" to 1,000' (Figure 6). The detailed studies of individual areas proceeded concurrently, using

Fig. 2

the maps at their original scale as fast as they became available. Furthermore, all studies utilized models. Figure 7 is a photograph of the basic 1" to 1,000' model on which the vertical scale is not exaggerated. Other detailed models of the site were prepared at 1" to 400' and finally at 1" to 100', directly from the Alster maps. These models were essential both for design and for presentation of design progress to the Air Force, the Secretary's Consultants and the Congressional Committees for consideration and criticism.

Also available to the Architect-Engineer were the aerial photographs from which the maps had been prepared. These photographs were used as stereoscopic pairs for study by Architectural design sections, by the U. S. Geological Survey in Denver, who prepared for the Air Force a series of geological

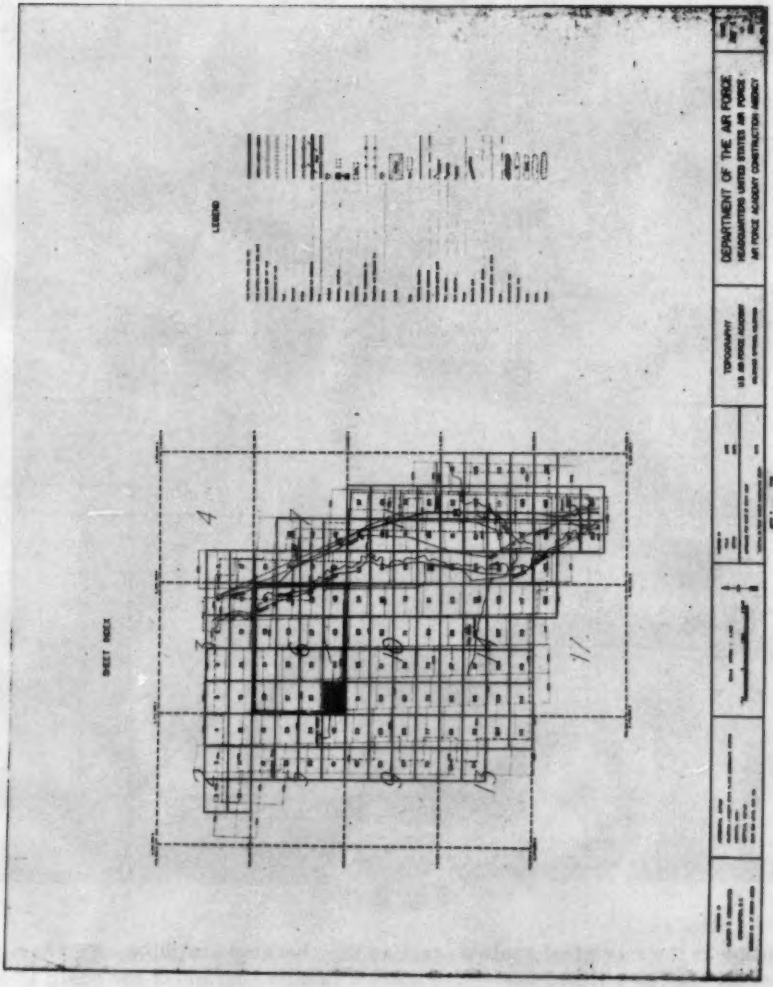
LEGEND
SHEET INDEX
DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
AIR FORCE ACADEMY CONSTRUCTION AGENCY
TOPOGRAPHY

Fig. 3

TOPOGRAPHY
U.S. AIR FORCE ACADEMY
DEPARTMENT OF THE AIR FORCE
AIR FORCE ACADEMY CONSTRUCTION AGENCY

Fig. 4

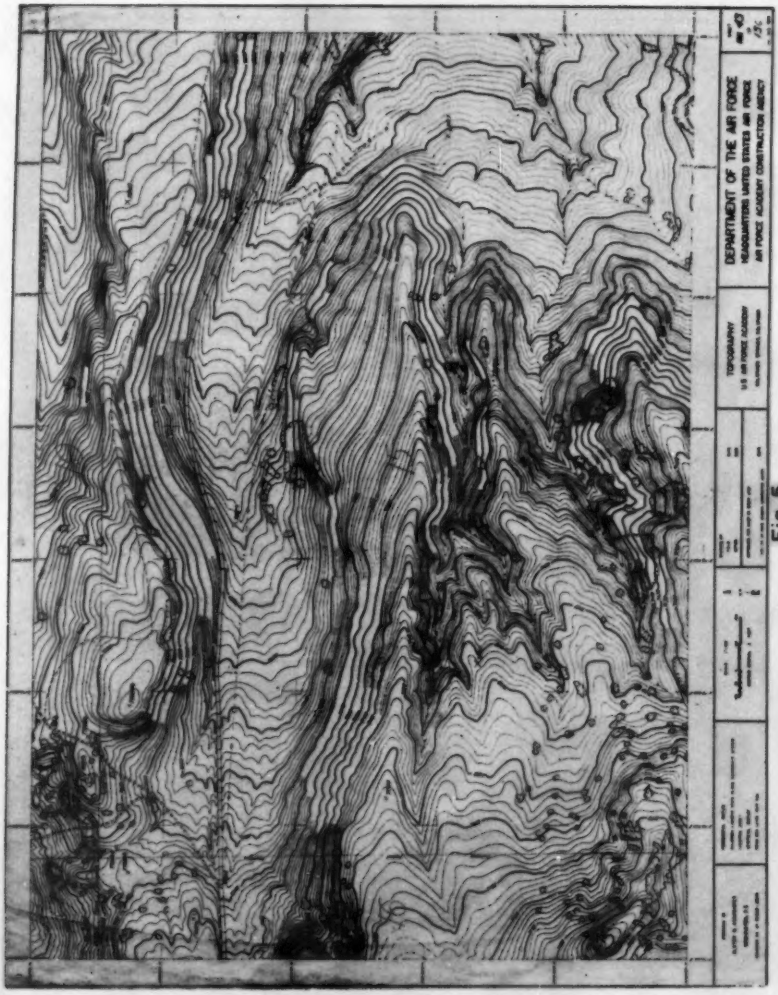
DEPARTMENT OF THE AIR FORCE
HEADQUARTERS, UNITED STATES AIR FORCE
AIR FORCE ACADEMY CONSTRUCTION AGENCY
TOPOGRAPHY

Fig. 5

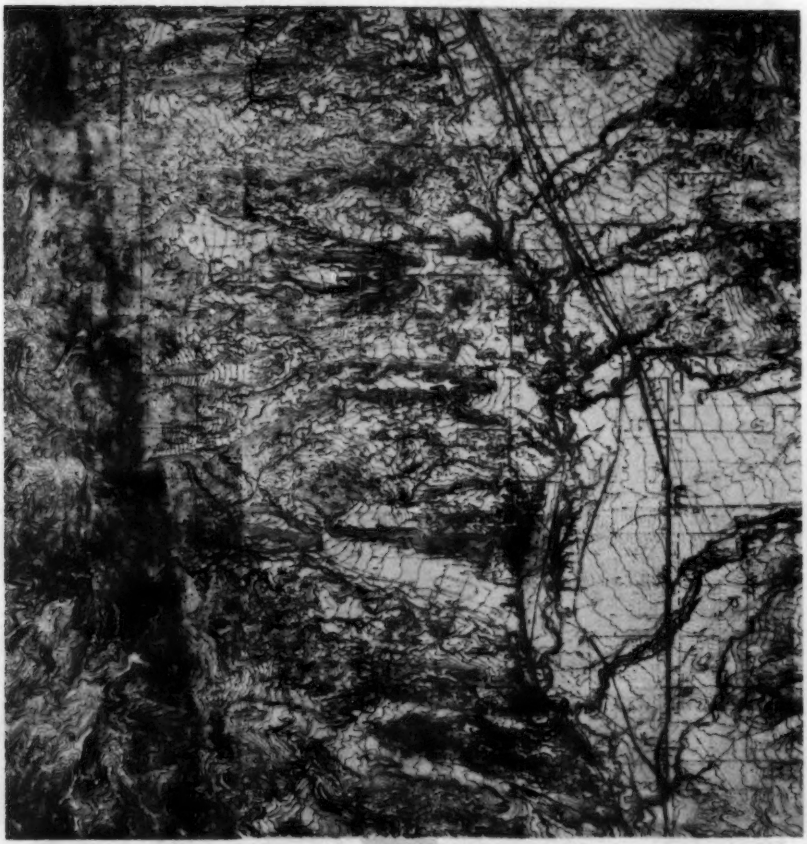

Fig. 6

maps; by Moran, Proctor, Mueser & Rutledge, associated in the design, in their study of the geological conditions in the airstrip area, and are continuing to be used for detailed analysis of tree cover and other terrain features. Figure 8 shows the photo mosaic corresponding to the 1,000' contour map. For a better picture of the general type of country, Figures 9 to 11 show a few of the many oblique aerial photographs which were taken, in addition, in order that designers might have a better "feeling" for the site. Figure 9 is a general view of the Site area from the northeast with the Black Forest in the foreground and Pike's Peak in the distance. The light area beyond the Black Forest is the Monument Creek Valley. Figure 10 looks south from the Maneuver Area. The formation in the foreground is Cathedral Rock, a natural land mark. Beyond Cathedral Rock is the Lehmann Valley, which will be used for the athletic fields. The Cadet Area is located on the higher mesa just beyond. Figure 11 shows one of the reasons why maps alone are insufficient for area planning. These boulders dropped from the Rampart Range would render otherwise suitable building areas completely impractical.

All of these map and photo studies were supplementary to extensive field

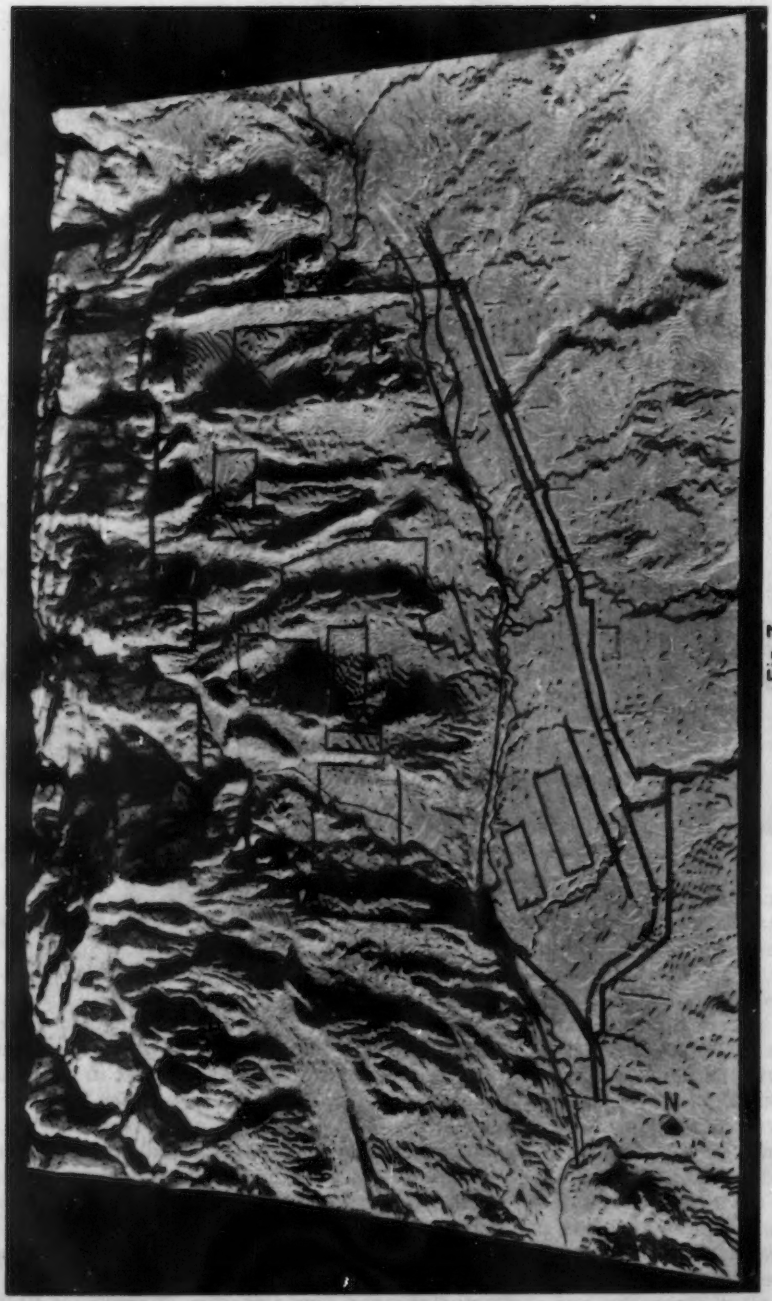

Fig. 7

Fig. 8

reconnaisance on the ground and in the air, in which the Air Force helicopters were extensively and most effectively used.

Finally the Master Plan evolved as shown on Figure 12. This discussion will not go into the many alternate solutions which were considered and modified or rejected, or the later revisions, but will indicate a few of the features of the final design which were influenced by topography. First, the airstrip. It will be noted that this is in the southeast corner and is shown here in a north northwest—south southeast alignment. This location, in addition to best meeting windrose conditions, was influenced directly by the terrain. Not only does this area present the only portion of the site level enough for practical construction of a 8,800 foot runway, but the approach from the north follows the lower ground in Monument Creek Valley and the projection of the bearing to the south, misses the business section of Colorado Springs and avoids interference with the air patterns of Peterson Field, the Colorado Springs airport west of the City. There is also sufficient relatively level ground for expansion if needed to 14,000 feet.

Fig. 9

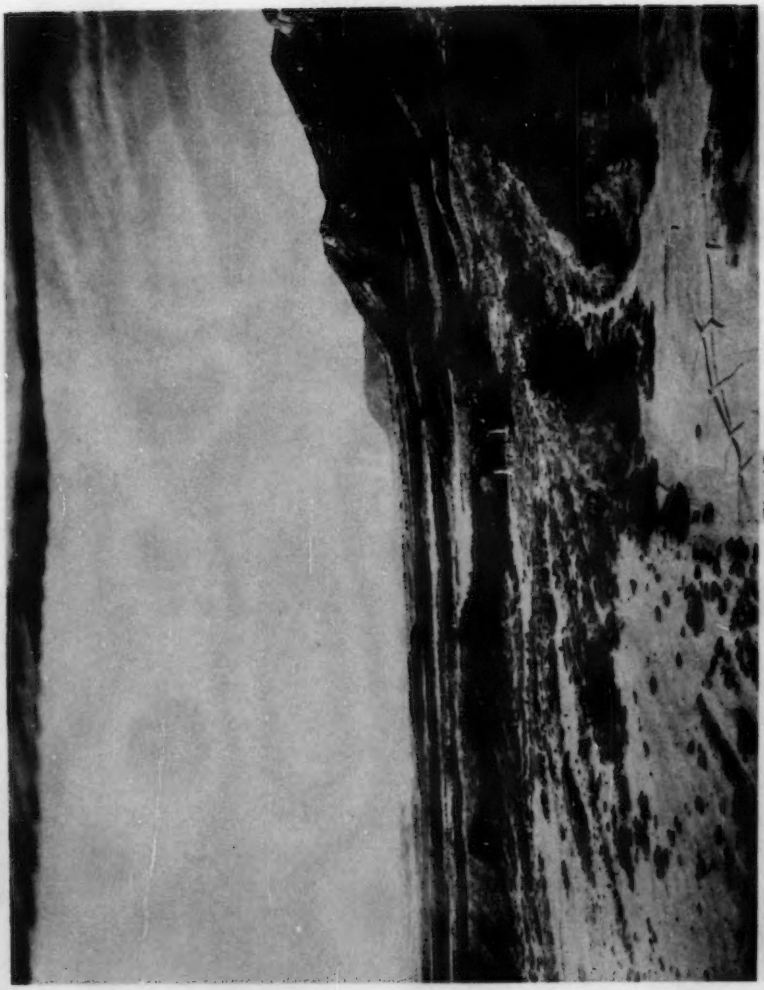

Fig. 10

Fig. 11

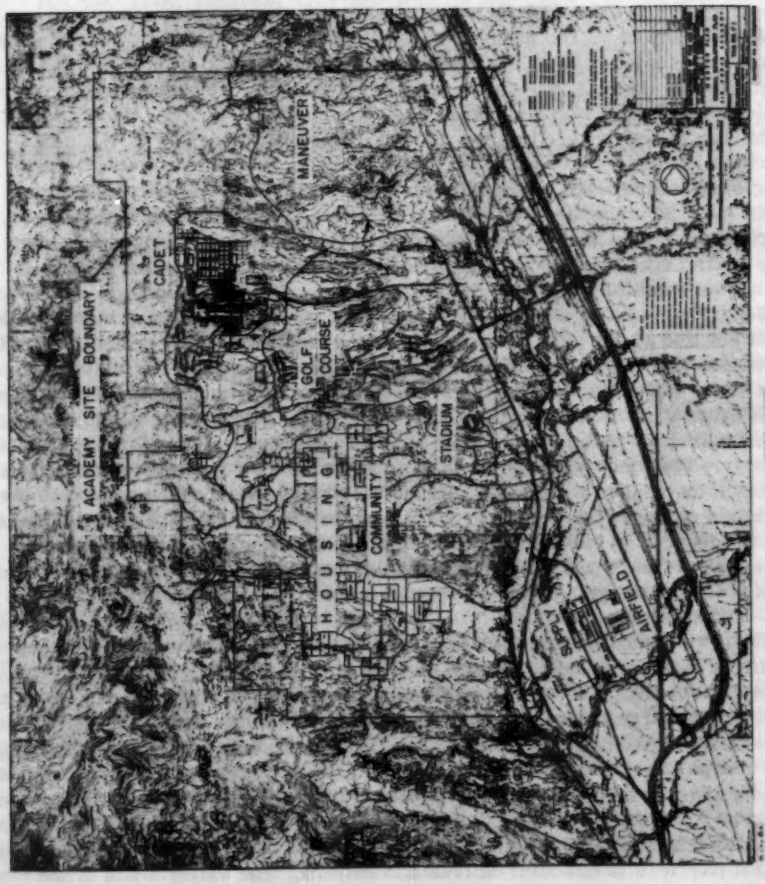
ACADEMY SITE BOUNDARY
CADET
MANEUVER
GOLF COURSE
HOUSING
COMMUNITY
STADIUM
AIRFIELD

Fig. 12

This location of the airstrip influenced most of the other elements of the site plan. The supply area was placed adjacent to the airfield not only because of its ready access to road and rail but to get both of these industrial features in the same area. It was also determined that academic and housing installations should be kept at least two miles away from the runway center line to minimize the jet plane noise nuisance.

While study of all the areas proceeded concurrently there is space to mention the reasoning back of the selection and development of only one typical example—the Cadet Area—as the most interesting as well as the focus of the whole Academy for which all other facilities furnish support. Except for some flight training at the Airfield the accommodations for the Corps of Cadets—quarters, dining and academic buildings; parade, drill and athletic fields; religious, recreational, and social facilities; and the administration of the whole must be concentrated in this area with adequate spacing but with no magnificent distances. The cadet day involves more important things than long walks between mess, quarters and classes. Many sites were studied; the one selected best fulfilled the many interrelated requirements.

Generally, buildable areas outside Monument Creek Valley, which is under the flight line of the jets, are confined to the relatively level areas on top of the mesas or in the broader valleys, and many of these are restricted in area. Here there is in conjunction, the broadest open valley and a magnificent mesa of adequate area overlooking the whole site, providing a focal point, in front of the back drop of the Range, visible as soon as the site comes in view on the highway. The campus descends in natural terraces from the dominating knoll on which the chapel is placed to the administration level—then in turn to the academic campus, the parade grounds and the athletic fields and buildings. The differences in elevation have been utilized to plane five story quarters and academic buildings which will have only two flights up and two flights down from the campus level—a consideration when climbing stairs at 7,000 feet—and at double time.

These two focal points, the cadet area and airfield, influenced the other facilities in between. The housing is generally in Douglas Valley and Pine Valley, too rolling and wooded perhaps for industrial or campus use, but an ideal pleasant residential environment. The community center is on the open mesa between them, accessible to both. From these areas, the staff and support troops can drive to work, generally to the Academy or the service areas without passing through other facilities. North of the cadet area is the maneuver area too rough for major building developments but relatively isolated and suitable for ranges and weapons demonstrations. Between these areas are the natural barriers of the alluvial fans and valleys. The valley south of the cadet campus is expected to be developed for recreational purposes including a golf course accessible both to the campus and the town with an officers club and BOQ's nearby. Like the Golf Course, the Stadium must be financed from other than Public Funds but its location has been planned.

All of these facilities must be tied together by the road net, which, following the terrain and field features and designed for 30 mph speeds, provides:

a) Access to the main highway north and south with interchanges at these entrances.
b) A 4-laned route along the easterly side of the site from which the transverse access roads extend to the west. This is designed to handle the stadium traffic.

c) Close relationship between the south entrance and the rail freight facilities in the Supply and Airfield area; between the north entrance and the rail passenger station and bus terminal; and with direct connection between these areas—all without traversing any of the intermediate areas.
d) A perimeter road—mountain type in the western areas—which will permit the casual visitors, with only limited time, to circle the site seeing all of it but without needing to intrude on the privacy of the cadet or housing areas unless they have personal business there.
e) The east-west access roads up to the valleys serving each of these important units at relatively east grades and providing 4-laned access to the cadet parade grounds, athletic areas, and field house all of which may be expected to draw traffic peaks for ceremonies and sports.

So much for the Master Plan. The topographical requirements for the detailed design involved the usual information from which alignment and grade of roads and utility lines were determined and for the location and grading of buildings. For these purposes, the 1" to 100' maps were used for preliminary alignments and for study of grades and obstructions. Particular attention has been paid to the present tree cover and, of course, to drainage (flash floods must be considered) since it is the intention to leave as much of the site as undisturbed as possible. It has, however, been necessary to walk proposed road and utility lines in the field since the value of individual trees is not apparent from the maps or the aerial photographs and there are a number of interesting rock formations which it is desired to retain. Minor adjustments of grade or line which in the rough areas are not apparent from the map, pay large dividends in costs and satisfactory results. The final alignment is staked in the field in the usual way.

With respect to buildings, particularly in the Cadet area as well as the other built-up areas, the preferred building locations have been laid out on a 1" to 50' map, supplemented by experimental staking in the field. These maps are, basically, a blow up of the 1" to 100' photogrammetric map with the precise contours and ground features verified or corrected, where critical, by plane table survey. This process is shown by the next group of illustrations. Referring back to Figure 5, the Alster 1" to 100' map, Figure 13, shows the 1" to 50' blow up of its NE quarter. Figure 14 is a 1" to 50' blow up of the aerial photograph. These photographs were registered with the contour maps and served as a basis for the detailed reconnaisance for tree cover. The figure shows the notations of the field parties forming part of the basis for final development of the corrected map which is shown in Figure 15. The working drawings for each area showing buildings locations, grading, pavements, and utilities will be prepared on a set of registered maps at this scale, with reproducibles which will be run off at various stages to simplify the design of additional facilities with proper relation to those already in place as the phased design and construction proceeds.

Finally, the matter of control. The Architect-Engineer was required to check the accuracy of the photogrammetric maps in order that the performance of the mapping contract might be certified. This was accomplished by a series of random traverses, to determine, by plotting ground survey data on the original maps, the location of prominent features and relative elevations all of which proved to be well within the requirements of the specifications. However, for purposes of computation of work quantities for payment, it is considered necessary for this project to run the usual cross sections

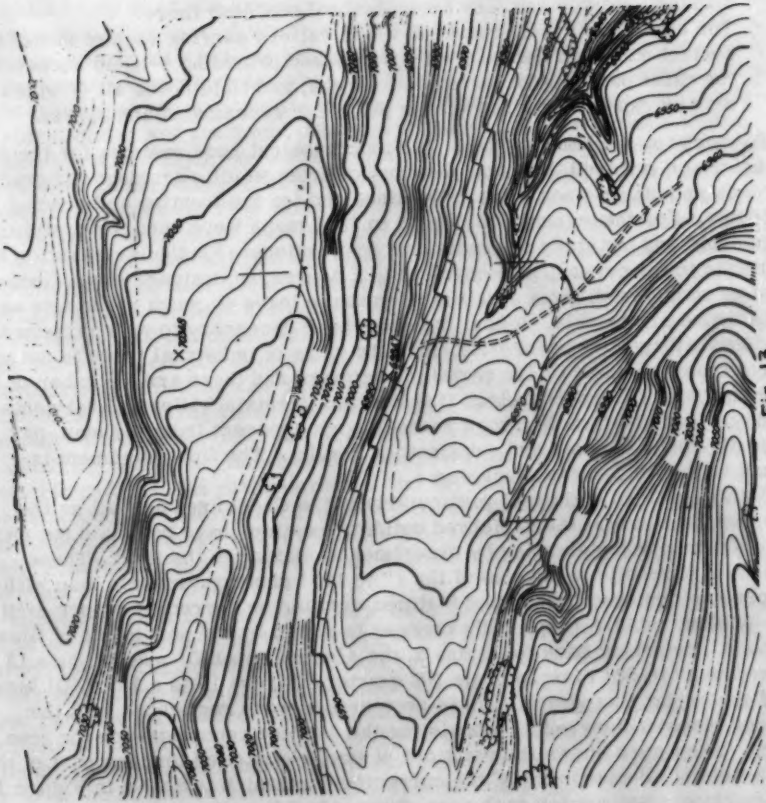

Fig. 13

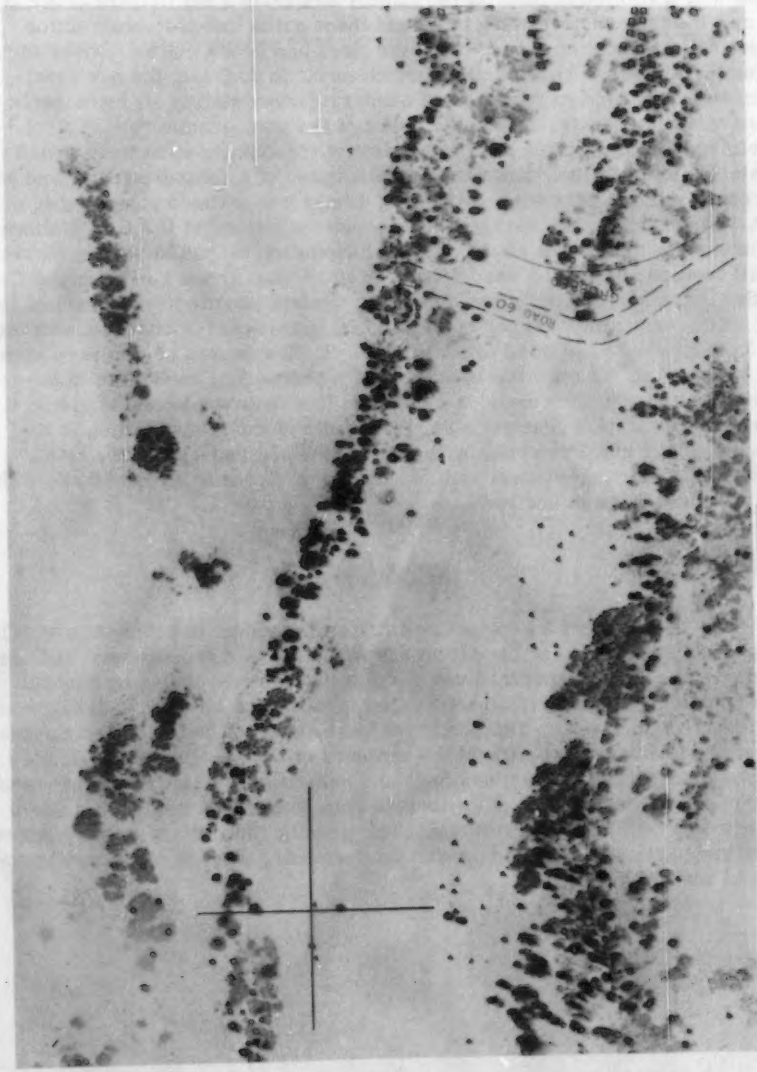

Fig. 14

before and after grading operations and, for detailed planning to verify critical building areas by plane table. The mapping contract included the establishment of a limited number of permanent monuments set to third order accuracy. It has been necessary to extend these grids into the construction areas finally selected in order that base lines and bench marks may be installed for the use of construction contractors. In addition, the Architect-Engineer is required to run a final Boundary Survey setting all monuments in connection therewith. The basic check of the photogrammetric control established a triangulation net independent of the triangulation work done by the Alster field parties. Since the establishment of a measured base line on the ground was not practical on the site, a base was utilized passing through the Academy area computed from the geodetic positions of U.S.G.S. stations approximately nine miles apart. This triangulation net, as shown on Figure 16 will be expanded as the need arises. The necessary work of checking the existing maps and extending the monument system justified refinement to the point where a maximum error of 1 in 20,000 is expected in contrast with the 1 to 5,000 permitted in third order accuracy. This degree of accuracy saves time which might be required to adjust the traverse and level lines of several parties, working as they must on a common line from separated stations, if reference points were less reliable. The basis of the triangulation, is the Lambert Conformal Projection with distances being reduced to sea level. The basis for vertical control is U. S. Coast and Geodetic Bench Marks with a datum plane of mean sea level.

SUMMARY

With as complicated a problem and site as is evident in connection with the design and construction of the Air Force Academy, the procurement and use of topographic information involves several procedures, including general maps supplemented by aerial photographs, ground and air reconnaissance and detailed ground surveys. The decisions for location of facilities and circulation routes are based not only on the contours of the terrain, but other elements such as ground cover, drainage and relationship to surrounding areas. For these purposes the use of up-to-date photogrammetric maps at a scale as large as 1"=100' proved invaluable and greatly reduced the time required for survey parties in the field as well as permitting a much more rapid progress of the design.

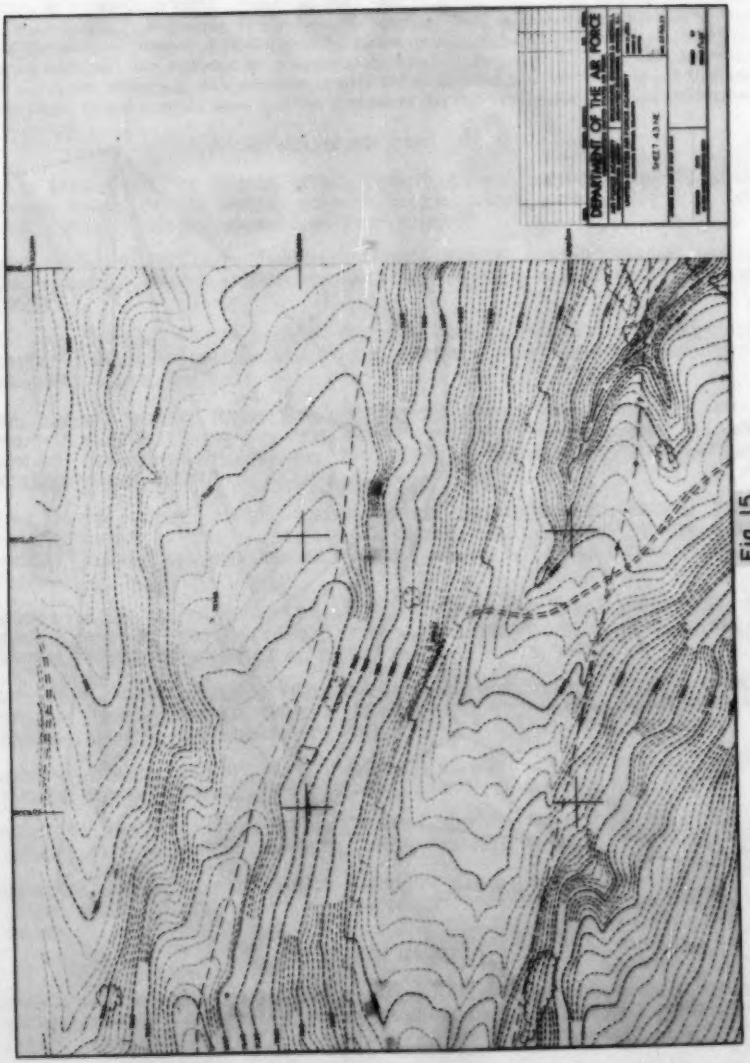

Fig. 15

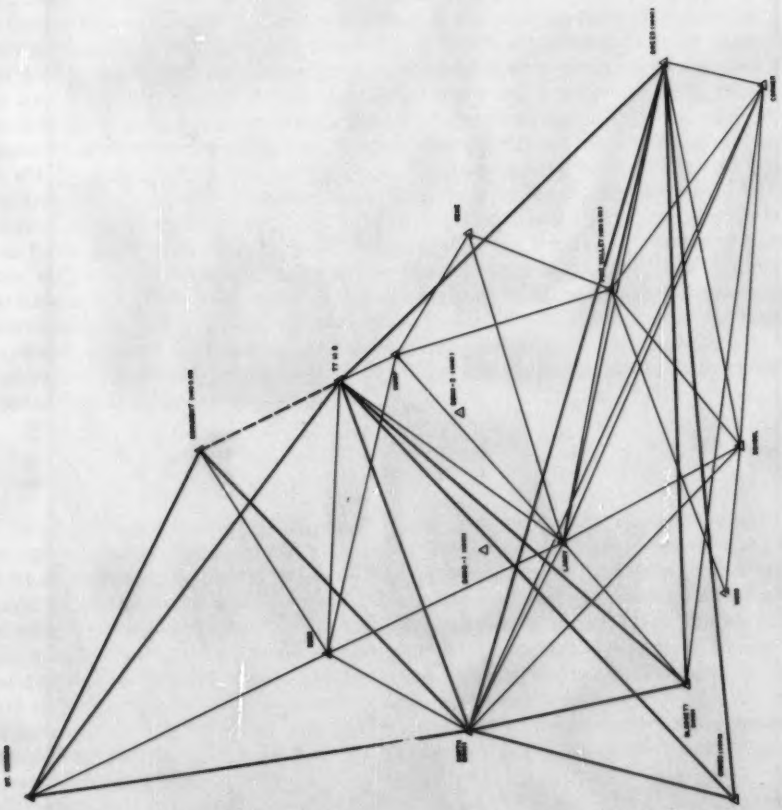

Fig. 16

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 861 is identified as 861 (SM1) which indicates that the paper is contained in issue 1 of the Journal of the Soil Mechanics and Foundations Division.

VOLUME 81 (1955)

MARCH: 634(PO), 635(PO), 636(PO), 637(PO), 638(PO), 639(PO), 640(PO), 641(PO)[c], 642(SA), 643(SA), 644(SA), 645(SA), 646(SA), 647(SA)[c], 648(ST), 649(ST), 650(ST), 651(ST), 652(ST), 653(ST), 654(ST)[c], 655(SA), 656(SM)[c], 657(SM)[c], 658(SM)[c]

APRIL: 659(ST), 660(ST), 661(ST)[c], 662(ST), 663(ST), 664(ST)[c], 665(HY)[c], 666(HY), 667(HY), 668(HY), 669(HY), 670(EM), 671(EM), 672(EM), 673(EM), 674(EM), 675(EM), 676(EM), 677(EM), 678(HY).

MAY: 679(ST), 680(ST), 681(ST), 682(ST)[c], 683(ST), 684(ST), 685(SA), 686(SA), 687(SA), 688(SA), 689(SA)[c], 690(EM), 691(EM), 692(EM), 693(EM), 694(EM), 695(EM), 696(PO), 697(PO), 698(SA), 699(PO)[c], 700(PO), 701(ST)[c].

JUNE: 702(HW), 703(HW), 704(HW)[c], 705(IR), 706(IR), 707(IR), 708(IR), 709(HY)[c], 710(CP), 711(CP), 712(CP), 713(CP)[c], 714(HY), 715(HY), 716(HY), 717(HY), 718(SM)[c], 719(HY)[c], 720(AT), 721(AT), 722(SU), 723(WW), 724(WW), 725(WW), 726(WW)[c], 727(WW), 728(IR), 729(IR), 730(SU)[c], 731(SU).

JULY: 732(ST), 733(ST), 734(ST), 735(ST), 736(ST), 737(PO), 738(PO), 739(PO), 740(PO), 741(PO), 742(PO), 743(HY), 744(HY), 745(HY), 746(HY), 747(HY), 748(HY)[c], 749(SA), 750(SA), 751(SA), 752(SA)[c], 753(SM), 754(SM), 755(SM), 756(SM), 757(SM), 758(CO)[c], 759(SM)[c], 760(WW)[c].

AUGUST: 761(BD), 762(ST), 763(ST), 764(ST), 765(ST)[c], 766(CP), 767(CP), 768(CP), 769(CP), 770(CP), 771(EM), 772(EM), 773(SA), 774(EM), 775(EM), 776(EM)[c], 777(AT), 778(AT), 779(SA), 780(SA), 781(SA), 782(SA)[c], 783(HW), 784(HW), 785(CP), 786(ST).

SEPTEMBER: 787(PO), 788(IR), 789(HY), 790(HY), 791(HY), 792(HY), 793(HY), 794(HY)[c], 795(EM), 796(EM), 797(EM), 798(EM), 799(EM)[c], 800(WW), 801(WW), 802(WW), 803(WW), 804(WW), 805(WW), 806(HY), 807(PO)[c], 808(IR)[c].

OCTOBER: 809 (ST), 810 (HW)[c], 811 (ST), 812 (ST)[c], 813 (ST)[c], 814(EM), 815(EM), 816(EM), 817(EM), 818(EM), 819(EM)[c], 820(SA), 821(SA), 822(SA)[c], 823(HW), 824(HW).

NOVEMBER: 825(ST), 826(HY), 827(ST), 828(ST), 829(ST), 830(ST), 831(ST)[c], 832(CP), 833(CP), 834(CP), 835(CP)[c], 836(HY), 837(HY), 838(HY), 839(HY), 840(HY), 841(HY)[c].

DECEMBER: 842(SM), 843(SM)[c], 844(SU), 845(SU)[c], 846(SA), 847(SA), 848(SA)[c], 849(ST)[c], 850(ST), 851(ST), 852(ST), 853(ST), 854(CO), 855(CO), 856(CO)[c], 857(SU), 858(BD), 859(BD), 860(BD).

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JANUARY: 861(SM1), 862(SM1), 863(EM1), 864(SM1), 865(SM1), 866(SM1), 867(SM1), 868(HW1) 869(ST1), 870(EM1), 871(HW1), 872(HW1), 873(HW1), 874(HW1), 875(HW1), 876(EM1)[c], 877 (HW1)[c], 878(ST1)[c].

FEBRUARY: 879(CP1), 880(HY1), 881(HY1)[c], 882(HY1), 883(HY1), 884(IR1), 885(SA1), 886(CP1), 887(SA1), 888(SA1), 889(SA1). 890(SA1), 891(SA1), 892(SA1), 893(CP1), 894(CP1), 895(PO1) 896(PO1), 897(PO1), 898(PO1), 899(PO1), 900(PO1), 901(PO1), 902(AT1)[c], 903(IR1)[c], 904 (PO1)[c], 905(SA1)[c].

MARCH: 906(WW1), 907(WW1), 908(WW1), 909(WW1), 910(WW1), 911(WW1), 912(WW1), 913 (WW1)[c], 914(ST2), 915(ST2), 916(ST2), 917(ST2), 918(ST2), 919(ST2), 920(ST2), 921(SU1), 922(SU1), 923(SU1), 924(ST2)[c].

c. Discussion of several papers, grouped by Divisions.

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